Ocular Injury Reduction From Ocular Protection Use in Current Combat Operations

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Background: **The mechanisms of modern warfare unfortunately have lead to many ocular injuries. This study attempts to quantify the effect of military combat eye protection on the incidence of ocular injury among US service members engaged in current combat operations.**

Methods: **We retrospectively gathered data from the Joint Theater Trauma Registry from patients entering level III hospital facilities in Operations Iraqi and Enduring Freedom from March 2003 to September 2006. The presence of ocular injury was the primary outcome measure; whereas severity of injury and the effect of eye protection education on compliance with wearing this protection were secondary outcome measurements.**

Results: **Ocular protection status at the time of injury was documented in 3,276 casualties during the collection period. Of these, 451 of 2,671 (17%) casualties who reported wearing ocular protection sustained an ocular injury and 155 of 605 (26%) casualties who reported not wearing eye protection suffered an eye injury ($p < 0.01$). After an intense ocular protection education program, there was a 16% increase in compliance of eye protection use in combat. Finally, when the severity of eye injuries are compared using an abbreviated injury scale, casualties with eye protection had decreased injury severity in addition to incidence ($p < 005$).**

Conclusion: **This study suggests that the military combat eye protection used by military personnel during current combat operations has resulted in significantly fewer and less severe ocular injuries. Further, results from this study may also suggest that Department of Defense educational programs may have been successful in increasing eye protection compliance.**

Key Words: **Ocular trauma, Combat eye injury, Combat eye protection.**

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With the changes in warfare over the last century that have led to increased use of explosive weaponry, the risks of eye injuries on the battlefield have increased.[1] Considering the small surface area of the eye compared the surface area of the rest of the face and body, this risk is substantially higher than would be expected.[2] However, many other factors affect incidence of eye injuries in the combat environment other than surface area alone. The development of high quality body armor has decreased the vulnerability of torso and abdomen, thereby increasing the proportion of injuries in vulnerable areas, such as the eyes. Also, in current combat operations, soldiers often expose only their head to engage the enemy while keeping their bodies behind cover. This behavior preferentially exposes the head, neck, and subsequently, eyes to rounds or fragments.[1,3] Finally, ocular tissue is more vulnerable to projectile injuries than other parts of the body. This vulnerability not only contributes to increased incidence, but increased severity of ocular injuries compared with the same impact elsewhere on the body.[4] Although some sort of protective lens is available to every soldier when entering the combat setting, the majority of eye injuries in previous studies were inflicted upon soldiers who were not wearing military combat eye protection (MCEP).[5,6] Most authors agree that the majority of minor and many severe ocular injuries can be prevented with the use of MCEP.[7–9] However, encouraging good MCEP compliance in the military has always been a challenge. Some dislike the esthetics of the eyewear, others find cleaning them onerous, whereas others complain of obscured vision from vapor accumulating during perspiration or exertion. Currently, many styles of MCEP are authorized and issued to soldiers entering combat, which range from military developed (Ballistic Laser Protective Spectacles, Special Protective Eyewear Cylindrical System, etc.) and commercially available systems (Wiley, Oakley, etc.).[10]

Ocular injuries in warfare have been fairly well documented throughout recent history. As the technology of warfare has changed, so has the incidence and types of eye injuries. In the nineteenth century, less than 1% of casualties sustained an ocular injury. During the World Wars, the incidence of ocular injuries increased from 2.0% to 2.5%, then 2.8% to 4.1% for Korea, 5% to 9% in Vietnam, and 13% in the first Gulf War.[1] A recent study examined 55 soldiers from Operation Iraqi Freedom (OIF) who sustained eye injuries with retained intraocular foreign bodies.[5] The authors reported that most injuries were due to blast injuries and re-

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sulted in casualties with multiple foreign bodies in one or both eyes. These foreign bodies tended to be metal, glass, stone, cement, or even bone and were usually contaminated. A second article reported on 207 eye casualties in Iraq in 2004 and reported that the largest proportion of eye injuries were due to fragmentary munitions (82%).[11] The authors concluded that almost 56 eye injuries (42%) would likely have been prevented if MCEP had been used. Furthermore, only 18 of 116 patients with open globes were wearing protection, suggesting that wearing protective eyewear may have decreased the risk of sustaining an open globe injury. A third article examined the number of eye casualties from March 2003 to December 2004. It reported that 17.3% of medical evacuations were for eye injuries, with 15.8% related to combat.[9] A final published account documents the incidence of eye injuries during the Iraq war from 2003 to 2005. This study includes 797 patients, 55% of which are US military. These authors concluded that only 9.3% of casualties in their data set were wearing MCEP at the time of the injury.[12]

MATERIALS AND METHODS

This report is a retrospective review of data gathered from the Joint Theater Trauma Registry (JTTR), a database of reviewed medical records from patients receiving treatment in level III or level IV care in the military health care system from OIF and Operation Enduring Freedom. Only patients with at least one International Classification of Diseases, 9th Revision, Clinical Modification diagnosis codes between 800.0 and 959.9 are entered into the database. Specifically, data for this report was queried for the time period between March 2003 and October 2006 with the inclusion of only active duty and activated guard and reserve service men and women. Patients who were not admitted to level III (theater hospital) or level IV (regional hospital) care were not included in this study. This includes many minor injuries that were managed on an outpatient basis and those patients who died before reaching at least level III care.

The JTTR is not a complete record of all wounded service men and women in OIF and Operation Enduring Freedom. Data tabulated and reported from the Department of Defense personnel and procurement statistics from the Statistical Information Analysis Division was used for comparison. The Statistical Information Analysis Division has more accurate data on total and monthly casualty reports.[13]

The severity of the ocular wounds were categorized by a table used in a previous article that assigns ocular severity according to the Abbreviated Injury Scale (AIS) codes into four levels. Not all casualties had AIS codes assigned, so ICD-9 codes were adapted to the injury scale (Table 1).[14] Although there is another injury scoring system, Ocular Trauma Score, this system was not used because of the way eye injuries were documented in the JTTR.[15]

Table 1 Ocular Scale

AIS or ICD-9 Code	Severity Level	Description
870	1	Laceration eyelid skin/periocular
870.1		Full-thickness laceration eyelid
870.2		Laceration eyelid involving lacrimal passage
918		Periocular superficial injury
921		Black eye NOS
921.1		Periocular contusion
940.1		Periocular burn
297099.1		Skin NFS
297202.1		Skin abrasion
297402.1		Skin laceration
297602.1		Skin contusion
297802.1		Skin avulsion
870.3	2	Penetrating orbital wound without foreign body
870.4		Penetration orbital wound with foreign body
870.8		Open wound ocular adnexa
870.9		Open wound ocular adnexa unspecified
918.1		Superficial corneal injury
918.2		Superficial conjunctival injury
918.9		Superficial eye injury
921.2		Orbital tissue contusion
941.22		Eye burn, second degree
240416.1		Conjunctiva injury
240499.1		Eye NFS
240602.1		Corneal abrasion
240699.1		Corneal injury NFS
241499.1		Uvea injury
241699.1		Corneal injury NFS
871	3	Ocular laceration without prolapse
871.1		Ocular laceration with prolapse
871.4		Laceration of the eye, unspecified
871.5		Penetration magnetic foreign body of the eye
871.6		Penetration magnetic foreign body of the eye
871.7		Ocular penetration unspecified
871.9		Open wound to the eyeball unspecified
921.3		Eyeball contusion
921.9		Eye contusion unspecified
940.4		Corneal/conjunctival burn
940.9		Eye/adnexa burn unspecified
240408.1		Tear duct laceration
240412.1		Choroidal rupture
240604.1		Corneal contusion
240604.1		Corneal hyphema
240606.1		Corneal laceration
240800.1		Iris laceration
241000.1		Retinal laceration
241200.1		Scleral laceration
251200.2		Orbital fracture NFS
251202.2		Orbital fracture closed
251204.3		Orbital fracture open/displaced
871.2	4	Eye rupture with tissue loss
871.3		Eye avulsion
950		Optic nerve injury
950.2		Injury to the optic pathways
950.9		Injury to the optic nerves/pathways unspecified
230202.2		Optic nerve contusion
230204.2		Optic nerve laceration
230206.2		Optic nerve avulsion
230299.1		Optic nerve injury NFS
240402.2		Eye avulsion/enucleation
241002.2		Retinal detachment
241202.2		Scleral globe rupture

Ocular Scale Adapted From a prior article for this study.[13]

AIS, Abbreviated Injury Scale; ICD-9 code, *International Classification of Diseases, 9th Revision, Clinical Modification*; NOS, not otherwise specified; NFS, not further specified.

RESULTS

A total of 6,589 charts were included and analyzed in this study with a total of 1,246 (19%) patients with at least one ocular or ocular adnexal injury. Of the 6,589 casualties in the database, 3,276 had the presence or absence of eye protection documented. Of these 3,276 casualties, 2,671 (41%) were reported to have been wearing eye protection at the time of injury, whereas 605 (9.2%) were reported to have not been wearing eye protection at the time of the injury. Of the patients in the database who had known eye protection status at the time of injury reported 17% (451/2,671) of those who were reported as wearing eye protection had an eye injury, whereas 26% (155/605) of those who were reported as not wearing eye protection had an eye injury ($p < 0.01$, Table 2, Fig. 1).

Table 2 **Eye Injury Numbers and Eye Protection Numbers From the Joint Theater Trauma Registry From March 2003 Until October 2006**

	Eye Protection	No Eye Protection	Unknown Eye Protection Status	Total
Eye injury	451 (36)	155 (12)	640 (51)	1246
Total injured	2671 (41)	605 (9.2)	3313 (50)	6589
Percentage of eye injuries	17%	26%		19%

Beginning September 2004, there was an aggressive campaign to encourage soldiers to wear MCEP. This campaign consisted of passing around a flyer with pictures of injured soldiers and strong encouragement by leaders to wear eye protection. On the flyer, one injured soldier had been MCEP (protective goggles) and had small fragmentary wounds surrounding his eyes but sustained no ocular injuries, whereas another soldier had not been wearing MCEP and sustained significant ocular injuries. To attempt to determine whether this campaign had any effect on compliance, the percentages of eye injuries on a monthly basis were estimated by using the JTTR database's eye casualty figures compared with the total casualty figures (Fig. 2). From March 2003 to August 2004, the percent of soldiers recorded wearing eye protection at the time of injury was 69%, whereas from September 2004 to August 2006, it was 85% ($p < 0.01$). The proportion of eye casualties during this time did not reflect an expected decline. From March 2003 to August 2004, the percentage of eye casualties was 17%, whereas from Septem-

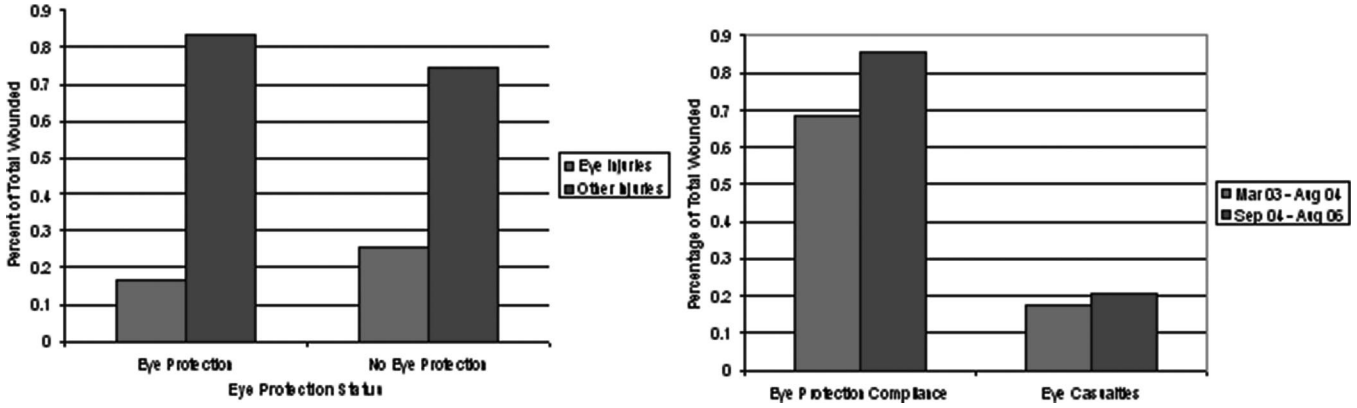

Fig. 1. *Graphs of the percentage of eye casualties compared with eye protection (left) and comparison of compliance and eye injuries before and after the eye protection campaign (right).*

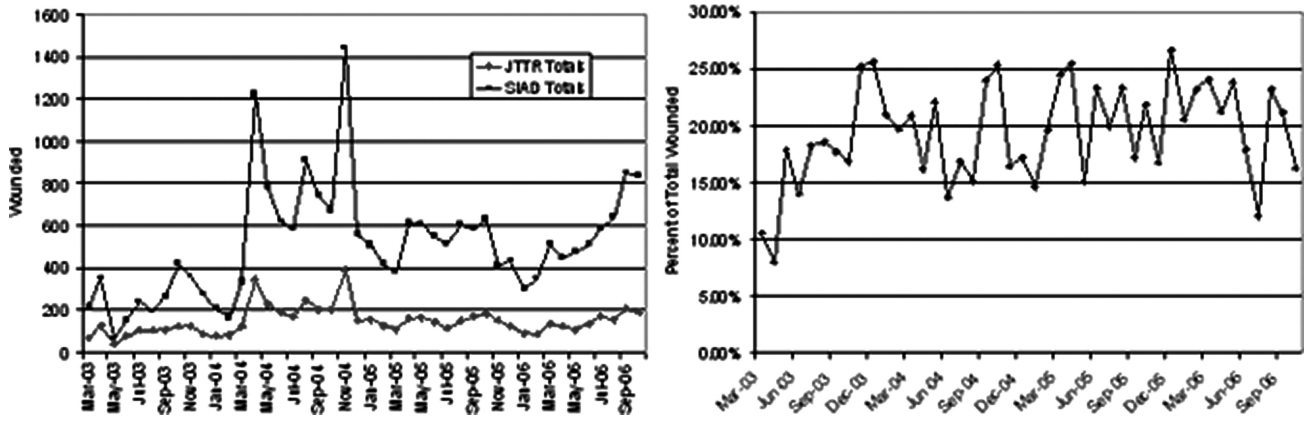

Fig. 2. *Graphs of the total casualty number comparison between the Joint Theater Trauma Registry and Statistical Information Analysis Division (left) and the percentage of eye casualties over time (right).*

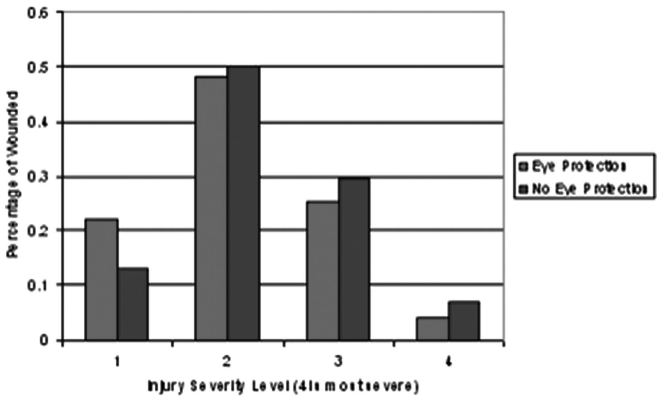

Fig. 3. *Eye protection compared with injury severities as assigned by the criteria in Table 1.*

ber 2004 to August 2006, the percentage of eye casualties increased to 20% ($p < 0.05$, Fig. 1).

By using the severity scale adapted from a previous study, the AIS and ICD-9 codes for the eye casualties were grouped into four severity categories, one through four: one being the least severe and four being the most severe. Eye casualties who had worn MCEP had a higher proportion of the least severe category, whereas the other three categories each had more eye casualties who had not worn eye protection. The only statistically significant difference was the severity category 1 ($p < 0.05$, Fig. 3).

DISCUSSION

The incidence of combat eye injuries has increased over time, sometimes despite the development of protective measures. To date, the published literature cites several articles over the past decades corroborating MCEP worn by soldiers in combat significantly decreases the numbers of minor and severe ocular and ocular adnexal injuries.[7–9] This study is no exception and further suggests that MCEP is a necessary requirement for service men and women to have issued before entering combat. There was a 9% reduction of eye injuries seen in soldiers who were reported as wearing MCEP compared to those soldiers who were reported as not wearing MCEP at the time of the injury. Further, the severity of eye injuries seemed to be lower when soldiers wore MCEP. These numbers, however, need to be taken in the context of the limitations of the study.

This study is a retrospective review from a database, which, although not complete, likely represents a cross section of the most severe casualties in the Iraq and Afghanistan wars. Further, the data were entered by reviewing medical records and not by the treating physician. Finally, the severity codes were entered based on assigned AIS and ICD-9 codes and not assigned by the treating physician. Therefore, reduction in eye injuries between casualties wearing MCEP and those who did not may not be the most reliable measure of efficacy in ocular injury reduction. However, it does suggest that MCEP is effective in reducing eye injuries in a modern combat environment. Moreover, this database only includes casualties that reach level III and level IV care (inpatient care); whereas minor injuries that soldiers receive are not taken into account. Casualties who sustained no eye injury because of protection may actually have lead to under reporting "true" effectiveness. MCEP in combat may be more effective as a means of preventing minor ocular injuries than more severe injuries.

The data regarding the compliance of MCEP before and after the Department of Defense-sponsored program encouraging eye protection use in September 2004 suggests that the program may have had a positive affect. However, multiple factors and confounding variables were involved and the change in compliance cannot be attributed to one source. Increasing compliance may have been enhanced by stronger encouragement from leaders; flyers, posters, and other educational information; or perhaps a realization among the soldiers that eye protection is an effective means of preventing injury on the modern battlefield. Oddly, if the eye casualty percentages are compared before and after September 2004, the percentage of eye casualties is actually higher after September 2004. With the increased compliance in this time period, the percentage of eye injuries would be expected to decrease. There are likely other variables affecting this result. One possible reason is that there were low numbers of recorded eye injuries early in the war, before September 2004. This low number of injuries may be because insurgency had not reached its full capacity early in the war and there were fewer explosive weapons being used on the battlefield. After the first few months, more explosive weaponry was used against US forces resulting in higher eye injury level for the reasons described earlier. The low incidence of eye injuries during the early months of the war may be a cause for the low-eye injury incidence during the March 2003 to September 2004 time period. Also, the style of MCEP worn may also be a factor, which was not available for data collection and consideration.

Finally, there is less question in the medical community about whether protective goggles decrease ocular injuries on the battlefield, however, the actual effectiveness of eye protection on the battlefield remains unknown. This study, although limited, does help substantiate the case for issuing high quality protective equipment to every soldier on the battlefield. Even though the equipment is available, it will likely always be a challenge to attain high levels of compliance among soldiers in a combat environment. However, with education and encouragement from leaders many additional soldiers may be saved from losing vision in one or both eyes.

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